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HARDWARE TEST PROGRAM FOR  
EVALUATION OF BASELINE  
RANGE/RANGE RATE SENSOR  
CONCEPT MONTHLY PROGRESS  
REPORT

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PREPARED FOR:

NATIONAL AERONAUTICS AND  
SPACE ADMINISTRATION  
GEORGE C. MARSHALL  
SPACE FLIGHT CENTER  
MARSHALL SPACE FLIGHT  
CENTER, ALABAMA 35812

PREPARED BY:

ALLIED BENDIX AEROSPACE  
BENDIX GUIDANCE SYSTEMS DIV.  
MISHAWAKA OPERATIONS  
400 SOUTH BEIGER STREET  
MISHAWAKA, INDIANA 46544

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## 1.0 INTRODUCTION

The Hardware Test Program for evaluation of the baseline range/range rate sensor concept was initiated 11 September 1984. This is the ninth report period since that award and covers the period 12 May through 11 June 1985.

During this report period effort was directed in two areas: (1) preparing material for the second program review, scheduled for 13 June, and (2) writing an interim report for the first phase of the Hardware Test Program covering the period 11 September 1984 through 11 June 1985.

A contract amendment adding a second phase has extended the Hardware Test Program through 10 December 1985. The objective of the added program phase is to establish range and range rate measurement accuracy and radar signature characteristics for a typical spacecraft target. A modified Bendix Millimeter Wave Instrumentation Radar will be utilized to perform the tests at Marshall Space Flight Center using an available 1/3 scale model of the Hubble Space Telescope as the target.

The test program is divided into four major tasks: Analysis, Radar Modification, Testing, and Documentation and Reviews. Progress has been reported in terms of these four tasks in previous progress reports; however, since this is the last report period for phase I of the Hardware Test Program (11 September 1984 through 11 June 1985), a summary of the program results will be presented in the following paragraphs.

## 2.0 HARDWARE TEST PROGRAM PHASE I SUMMARY

Phase I of the Hardware Test Program was designed to reduce the risks associated with the Range/Range Rate (R/R) Sensor baseline design approach. These risks are associated with achieving the sensor performance required for the two modes of operation, the Interrupted CW (ICW) mode for initial acquisition and tracking to close-in ranges, and the CW mode, providing coverage during the final docking maneuver. The risks associated with these modes of operation have to do with the realization of adequate sensitivity to operate to their individual maximum ranges and, in the case of the CW mode, sufficient range measurement accuracy to enable docking with a space-craft target.

The procedure used for risk assessment was an in-depth performance evaluation of existing Random Signal Radars (RSR) which were appropriately modified to test bed configurations emulating the ICW and CW modes of operation proposed for the OMV R/R Sensor configuration. A brief description of the test results is presented in the following paragraphs followed by a risk assessment.

### 2.1 Interrupted CW Mode Test Results

The objective of the interrupted CW (ICW) mode testing was to establish the performance of a 94 GHz radar designed to operate in the ICW mode. An existing Random Signal Radar (RSR) was modified to test bed configuration and tests were performed to establish the sensitivity achievable with respect to the design value. The importance of these tests was to establish the risk associated with the R/R sensor baseline approach selected for the

OMV application. Of particular concern was the realization of adequate sensitivity which requires implementing sufficient transmitter and receiver on-off ratios to keep the leakage power below receiver noise level and thereby prevent performance degradation.

Results of the ICW mode tests are summarized in Table 1. The overall performance which is the measured system sensitivity is 6 dB less than the test bed radar design goal. The primary discrepancy was found to be in terms of the correlator gain factor realized which was 6 dB less than the design goal. Several factors were listed in the previous monthly progress report as potential causes of the discrepancy in correlator gain, extraneous noise introduced by PRF generator, excessive video bandwidth, and detector characteristics being the major areas identified for further investigation. A comment on each item listed in Table 1 follows.

Noise Figure - The measured noise figure plus system losses of 24 dB is in agreement with the test bed radar design value of 24 dB. As will be discussed later, this (24 dB) does not represent the minimum achievable value assuming currently available hardware.

Transmitter-Receiver Isolation - The transmitter-receiver isolation is a measure of how well the transmitter path is isolated from the receiver path. When operating in the interrupted CW mode, the receiver is turned off while the transmitter is on, and when the receiver is listening for a target return, the transmitter is turned off. The measured on-off ratio of 99 dB is 6 dB less than the test bed radar design goal of 105 dB, and the differential is attributed to reduced isolation achieved through a circulator connecting the transmitter and receiver paths. It is anticipated that the level of isolation can be increased by increasing the number of on-off switches in the transmitter-receiver path.

Leakage/Noise Power Ratio - The net effect of not achieving infinite isolation between the transmitter and receiver channels is the introduction leakage power which competes with the target return signal. If the leakage power level is equal to the receiver noise power, the net effect is a 3 dB reduction in system sensitivity. By achieving a leakage power level at least 10 dB below receiver noise power the degradation in sensitivity becomes negligible, consequently, the design goal is a leakage power level at least 10 dB below receiver noise.

The measured leakage power was 6 dB below the receiver noise and results in a 1 dB degradation in sensitivity. It is anticipated that by increased cable shielding and repackaging the leakage level can be reduced to a level exceeding the design goal.

Correlation Gain - A correlator gain within 1 dB of the theoretical value has been achieved in previous RSR implementations. The cause of the 6 dB discrepancy is presently under investigation.

Range Resolution - The range resolution achieved is reasonable and is acceptable.

System Sensitivity - The measured sensitivity is 6 dB below the design value and, as indicated previously, the discrepancy is primarily attributable to a lower than anticipated correlator gain.

TABLE 1  
ICW MODE TEST RESULTS

| <u>PARAMETER</u>               | <u>DESIGN</u> | <u>MEASURED</u> |
|--------------------------------|---------------|-----------------|
| NOISE FIGURE                   | 24 dB         | 24 dB           |
| TRANSMITTER-RECEIVER ISOLATION | 105 dB        | 99 dB           |
| LEAKAGE/NOISE POWER RATIO      | < -10 dB      | - 6 dB          |
| CORRELATOR GAIN                | 47 dB         | 41 dB           |
| RANGE RESOLUTION               | 2.4 M         | 2.5 M           |
| SYSTEM SENSITIVITY             | - 110 dBm     | - 104 dBm       |

## 2.2 Risk Assessment ICW Mode

Although the baseline R/R sensor parameter design goals differ from the test bed radar parameters, the hardware tests were designed to provide insight into the degree of risk associated with the baseline approach. The baseline design parameters achieve the same sensitivity as the test bed radar but higher transmitter power and, consequently, higher transmitter-receiver isolation are required. A list of the R/R sensor design goals and risk assessment associated with the ICW mode of operation is presented in Table 2.

Two risk items, the noise figure plus system losses and transmitter-receiver isolation, are discussed further below.

TABLE 2  
RISK ASSESSMENT-ICW MODE OF OPERATION

| <u>RISK FACTOR</u>              | <u>DESIGN GOAL</u> | <u>EXPECTED VALUE</u> | <u>COMMENTS</u>   |
|---------------------------------|--------------------|-----------------------|---|
| NOISE FIGURE PLUS SYSTEM LOSSES | 12 dB              | 17.5 dB               | UTILIZES MIXER/HIGH GAIN POST AMPLIFIER COMBINATION.  |
| W-BAND SOLID STATE SOURCE       | 800 mW*            | 800 mW                | REQUIRES DEVELOPMENT OF POWER COMBINER.   |
| TRANSMITTER-RECEIVER ISOLATION  | 133 dB             | 120 dB                | REQUIRES IMPROVED SHIELDING, COMPONENT REPACKAGING AND POSSIBLY FEEDTHROUGH NULLING TECHNIQUES. |
| CORRELATOR GAIN                 | 31 dB              | 30 dB                 | A CORRELATOR EFFICIENCY FACTOR CORRESPONDING TO 30 dB CORRELATOR GAIN HAS BEEN DEMONSTRATED.    |

\* POWER LEVEL REQUIRED TO REALIZED 500 mW AT TRANSMITTING ANTENNA (ASSUMES 2 dB LOSSES).

Noise Figure Plus System Losses - Achieving the design goal of 12 dB would require development of a W-band (94 GHz) preamplifier. At the present time preamplifiers are available at frequencies up to 35 GHz and it doesn't appear that the frequency coverage will extend to 94 GHz in the near future. By utilizing an available mixer/high gain-low noise figure post amplifier, a system noise figure plus losses totaling 17.5 dB could be realized and this is the expected value.

Transmitter-Receiver Isolation - By improved shielding, component repackaging, and possible utilization of feedthrough nulling techniques, it is anticipated that the transmitter-receiver isolation (which in this context includes leakage power as well as effective transmitter and receiver on-off ratios) could be increased to a level of 120 dB.

The revised R/R sensor design goals are listed in Tabl. 3. Combining the increase in noise figure plus system losses and decrease in realized transmitter-receiver isolation would result in an 8 dB increase in target RCS (Radar Cross Section) threshold at 8 nmi or the same RCS threshold (10m<sup>2</sup>) at a range of 5.1 nmi.

TABLE 3  
COMPARATIVE ICW MODE SENSOR PERFORMANCE

| <u>PARAMETER</u>                | <u>DESIGN GOAL<br/>INITIAL</u> | <u>DESIGN GOAL<br/>REVISED</u> |
|---------------------------------|--------------------------------|--------------------------------|
| NOISE FIGURE PLUS SYSTEM LOSSES | 12 dB                          | 17.5 dB                        |
| RECEIVER NOISE POWER LEVEL      | - 96 dBm                       | - 90.5 dBm                     |
| TRANS.-RECVR. ISOLATION         | 133 dB                         | 120 dB                         |
| LEAKAGE POWER                   | - 106 dBm                      | - 93 dBm                       |
| CORRELATOR GAIN                 | 31 dB                          | 30 dB                          |
| RCS THRESHOLD @ 8 NMI           | 10 M <sup>2</sup>              | 60 M <sup>2</sup>              |
| INITIAL ACQUISITION SEARCH TIME | 9 MIN                          | 9 MIN                          |

### 2.3 CW Mode Test Results and Risk Assessment

The objective of the tests was to demonstrate R/R sensor operation in the CW mode with the system sensitivity and range measurement accuracy required during the final stages of docking. Achieving the baseline sensor design goals requires an isolation between the transmitter and receiver paths of 120 dB, and a range measurement accuracy of 6 inches. Results of the CW mode tests which are listed in Table 4 indicate that these goals are achievable. The risk associated with the CW mode of operation listed in Table 5 is providing the required range measurement accuracy at target ranges less than 1 meter. Glint and scintillation effects at ranges less than 1 M may cause excessive range measurement errors.

A detailed description of the Hardware Test Program with results is included in the interim report which is scheduled for publication in the near future. The test program was successful in identifying areas of risk and thereby reducing the risk associated with the R/R sensor design. The next phase of the Hardware Test Program will provide further data required for development of the R/R sensor. In particular, the second phase testing is designed to provide target signature data of a representative spacecraft target, the HST. This data will be utilized in designing the tracking loops required for anticipated extended target signature characteristics.

TABLE 4  
CW MODE TEST RESULTS

- ANTENNA ISOLATION EXCEEDING 125 dB ACHIEVED FOR TWO 22° ANTENNAS.
- RANGE STEP SIZE OF 9.4 cm/STEP AND RANGE ACCURACY OF  $\pm$  5 cm. CONFIRMED FOR RANGES 1 TO 61 METERS.
- FOR RANGES LESS THAN 1 METER, ERRORS USUALLY EXCEEDED 0.15 M. TARGET CHARACTERISTICS, SCINTILLATION, AND MULTI-PATH APPEARED TO BE THE PROBLEMS.

TABLE 5  
RISK ASSESSMENT-CW MODE OF OPERATION

| <u>RISK FACTOR</u>              | <u>DESIGN GOAL</u>        | <u>EXPECTED VALUE</u>                                     | <u>COMMENTS</u>  |
|---------------------------------|---------------------------|---|--|
| TRANSMITTER-RECEIVER ISOLATION  | 120 dB                    | 120 dB Min.   | CW MODE ISOLATIONS GREATER THAN 120 dB HAVE BEEN MEASURED.   |
| ACCURATE TRACKING TO ZERO RANGE | 6 IN ACCURACY TO ZERO FT. | > 6 IN ACCURACY TO 1 M;<br>< 6 IN ACCURACY 1 M TO DOCKING | ACCURACY BETTER THAN 6 IN MEASURED BEYOND 1 M.<br>GLINT & SCINTILLATION CAUSED EXCESSIVE ERRORS AT RANGES < 1 M. |

### 3.0 PLANS FOR NEXT REPORT PERIOD

In addition to completing the report covering the first phase of the Hardware Test Program, work will begin on the second phase. The initial effort will be directed at modifying the MMW Instrumentation radar to the required test bed configuration.

### 4.0 COSTS AND PERCENT CONTRACT COMPLETION

#### Costs

The program expenditures will be reported on a monthly basis. The expenditures through May 1985 were \$94,422.

#### Percent Completion

The estimated physical completion of the contract for phase one effort through the reporting period is 95%. Effort on phase two will begin during the next report period.